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REPETITIVE SERIES INTERRUPTER II

EG and G, Incorporated
Salem, Massachusetts

December 1976

Research and Development Technical Report
ECOM-76-1301-1

REPETITIVE SERIES INTERRUPTER II

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First Triannual Report for the Period 26 January 1976 - 23 May 1976

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Work performed on the Repetitive Series Interrupter during the period 26 Jan 76 to 23 May 76 is described in this First Triannual Report. The objective of this effort is to obtain an improved exploratory development model of the 15 kilovolts series interrupter. Designs of experimental devices, based on hydrogen thyratron techniques, are described. A test circuit has been constructed, and the test results obtained to date are discussed.

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1.0 FOREWORD

This first triannual report covers work done from 26 January 1976 to 23 May 1976 on Contract DAAB07-76-C-1301 to obtain an improved exploratory development model of the 15 kilovolt series interrupter. The work was performed by the EG&G, Inc., Electronics Components Division, Salem, Massachusetts, for the U.S. Army Electronics Command, Fort Monmouth, New Jersey.

2.0 OBJECT

The object of the work is to fulfill the requirements of the Electronics Technology and Device's Laboratory Technical Guidelines entitled, "Repetitive Series Interrupter II," dated 24 June 1974.

3.0 BACKGROUND

The purpose of this program is to develop improved models of the 15 kilovolt interrupter, with minimum magnetic field requirements, minimum voltage drop (less than 350 volts) and minimum size. The program is to include a simultaneous theoretical design study to aid in the experimental work and also to develop proposed designs for 30 and 50 kilovolts.

The required electrical conditions are:

Open circuit hold-off voltage	15 kilovolts minimum
Closed voltage drop	350V maximum
Fault peak current	300 A maximum
Normal average current	0.8 A minimum
Normal peak current	25 A maximum
Repetition rate	1000 Hz maximum
Life	1000 hr minimum
Fault interruptions	20,000 minimum
Interruption magnetic field energy	50 joules maximum

The basic design approach is similar to that of past interrupter contracts in this series, reported in ECOM 00123-F of 1967 and ECOM 73-0320-5 of 1974. In these designs, the cathode, grid and anode structures of thyratrons are used with an interaction region added to the device. In all cases thus far, the interruption occurs along a linear (or folded linear) discharge column when a sufficiently intense magnetic field is applied perpendicularly to the column.

The work to date shows that the most significant problems are high tube drop (of the order of several hundred volts to 3 kilovolts) and high magnetic field required to interrupt. Accordingly, the EG&G effort is directed first toward determining the effects of the significant variables on these characteristics.

4.0 THE COURSE OF THE INVESTIGATION

4.1 Test Circuit

Figure 1 shows the circuit diagram of the discharge portion of the tester constructed for this program. Either a normal discharge pulse of up to 25 amperes, or a fault current discharge of up to 300 amperes can be applied to the device under test. The Repetitive Series Interrupter (RSI) cathode is always at ground potential in this circuit in order to make correct voltage measurements possible. A thyratron and a Pulse Forming Network (PFN) arrangement has been used to provide the normal pulse. A vacuum triode might be better to simulate the normal effects of a Crossed-Field Amplifier (CFA) or Traveling-Wave Tube (TWT) series element, particularly to determine jitter or other triggering characteristics; therefore, it will be considered for use later in the program.

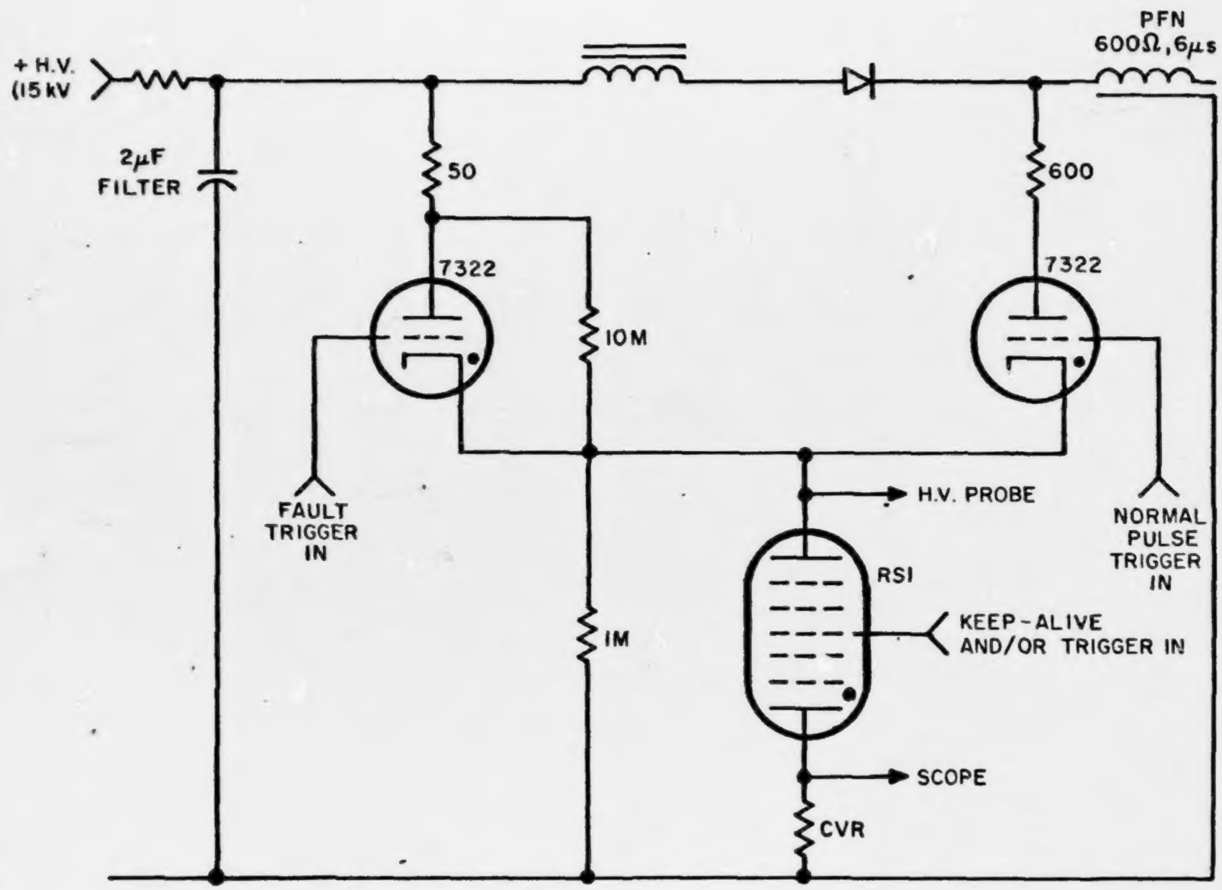

Figure 1. RSI Test Circuit.

The magnetic field pulse is now provided by a capacitor discharge, controlled with a triggered spark gap, through a coil wound on a silicon-iron core. The present arrangement uses two Arnold AH-1154 cores, giving pole face 6 by 2 inches. Five turns are wrapped on the cores in series with a 2 microfarad capacitor, a damping resistor, and a triggered spark gap. This circuit gives a magnetic pulse rise time of approximately 10 microseconds with a damped pulse width of about 60 microseconds (1/3 amplitude).

4.2 Tube Design

Three tubes have been constructed in this program, as shown in Figures 2, 3, and 4.

In previous work on these devices, the interaction region has been added to the anode of the thyratron, similar to a post-anode structure. Tube RSI 002 (Figure 3) is such a device. This construction has required that the normal discharge pass through the anode, while the recovery and hold-off requirements have necessitated that the anode structure be baffled or otherwise obstructed. It is believed that some of the high tube drops, instabilities, and triggering problems, which have been observed, were caused by the anode transition region.

One possibility to overcome this difficulty is shown in Figure 2 (Tube RSI 001). In this construction, the interaction region is placed between the cathode and control grid. The anode transition is eliminated; the keep-alive discharge can now be passed through the interaction column, which should also aid triggering. This tube can be operated either as a free-running diode or as a triggered thyratron.

Tube RSI 003 (Figure 4) is a five-section version of Tube RSI 001. This tube is intended for parametric studies, particularly to determine length effects.

All three tubes were filled with hydrogen at 0.40 torr.

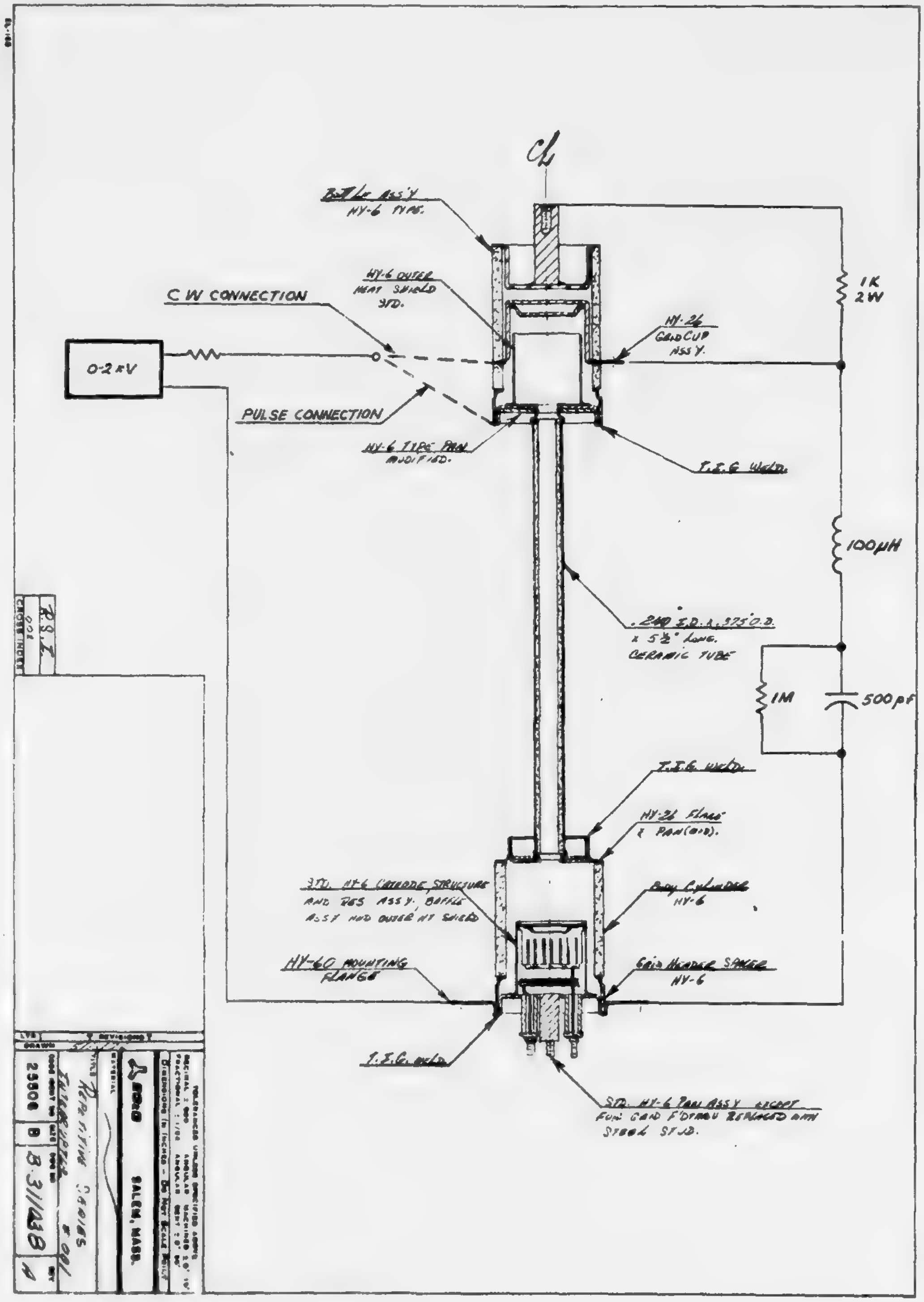

Figure 2. Tube RSI 001 and Connections.

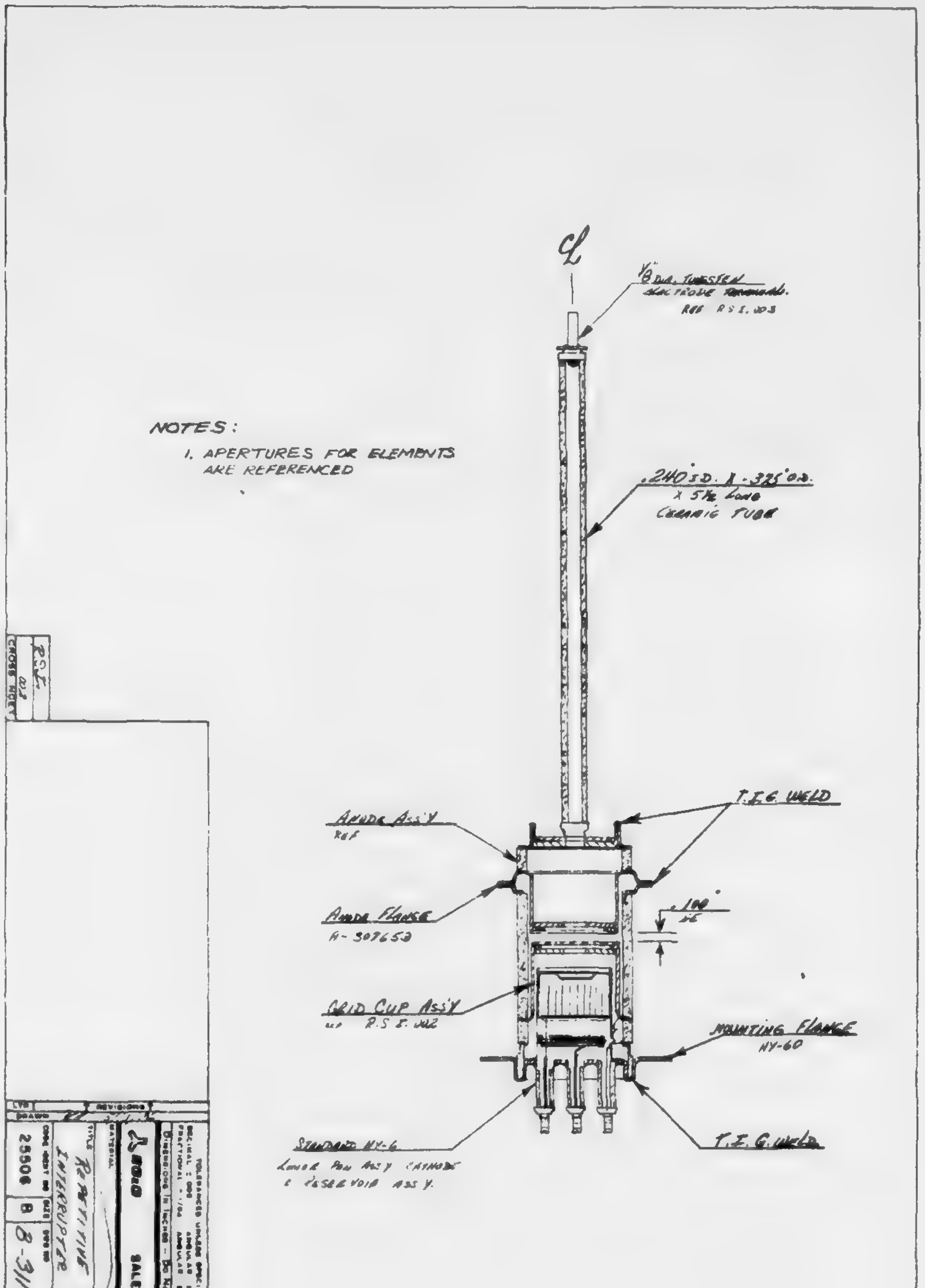

Figure 3. Tube RSI 002.

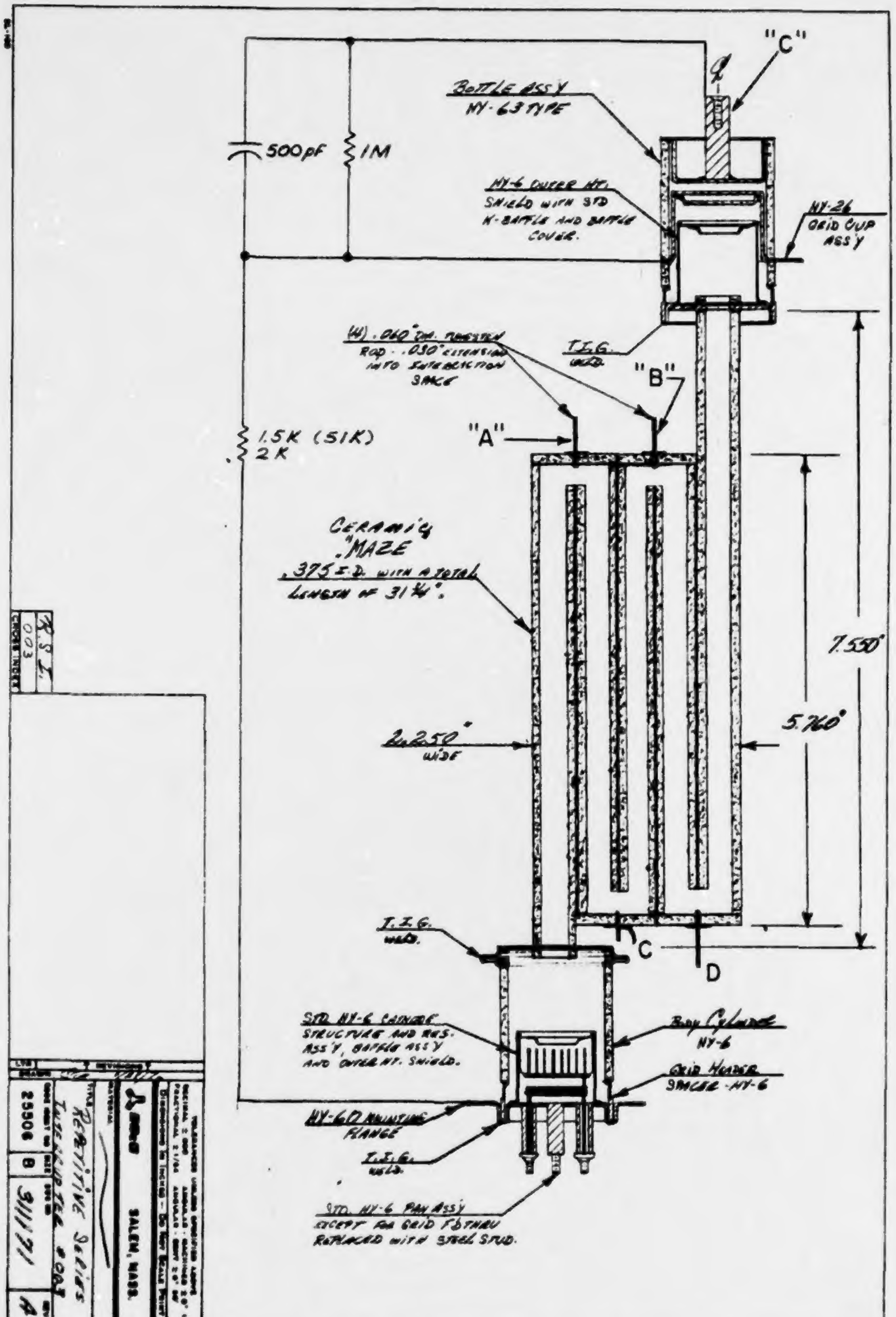

Figure 4. Tube RSI 003 and Connections.

4.3 Test Results

Table 1 lists typical tube drop measurements for Tubes RSI 001 and RSI 002. These results are at 25 amperes peak, at 3 microseconds.

Table 1. Tube Drop [etd (volts) at 25 amperes] Measurements for Tubes RSI 001 and RSI 002.

	Reservoir Voltage, E_r (Vac)	5.6	6.4	7.2
	Estimated Tube Pressure (torr)	0.30	0.42	0.54
Tube		e_{td} (volts)		
001	Grid-cathode interaction	190	230	260
002	Anode interaction	420	380	370

It is typical that the tube drop in both Tubes RSI 001 and RSI 003 increases with increasing pressure, while the opposite has usually been observed in Tube RSI 002. Some further preliminary results on tube drop are given below:

A. The anode interaction on Tube RSI 002 was unstable in its characteristics, as were several of its predecessors.

B. Tube drop across Tube RSI 002 decreases with time by as much as a factor of two. With a long pulse, a constant value is usually obtained after about 10 microseconds. Tube drop across Tube RSI 001 seems to be constant after the first fraction of a microsecond.

C. Both tubes are likely to produce bursts of noise (seen on the tube voltage waveforms), and sometimes current chopping. These effects are strongly dependent on the external circuitry.

Several experiments with the use of keep-alive showed that for Tube RSI 001 there is a critical value of keep-alive (about 12 milliamperes) below which the interaction column plasma is unstable. Above this value, the tube would always go into conduction with delay time (less than 0.2 microseconds) with applied anode voltage of 2 kilovolts or higher.

Preliminary interruption measurements were made with the most significant of the results listed in Table 2.

Table 2. Magnetic Field to Interrupt.

Tube	Fault Condition		Magnetic Field to Interrupt Field (kG)
	Voltage (kV)	Current (A)	
001 6 in., G-K Region	2	40	7.9
002 6 in., Anode Region	2.5	50	10.7
003 30 in., G-K Region	5	100	4.75
	10	200	6.5
	15	300	8.3

5.0 CONCLUSIONS

The results to date indicate that the insertion of the interaction region into the grid-cathode space has much of the desired result; that is, discharge stability is improved, triggering improved, and voltage drop reduced. Several tubes of the older design, with the interaction region attached to the anode, are available and will be tested in this program to help establish the relative merits of these designs.

Reduction of the voltage drop during normal conduction remains a necessity.

6.0 RECOMMENDATIONS FOR FUTURE WORK

The first priority in the next period will be parametric studies to determine interruption field, voltage drop, and free-running trigger characteristics as a function of length, supply voltage, fault current, tube pressure, and interaction-column diameter.

Data of tube drop and current as a function of magnetic field during interruption will be obtained for use in the theoretical work.

Insofar as possible, optical studies will be made to determine spatial distribution of the plasma and emission spectra during interruption.